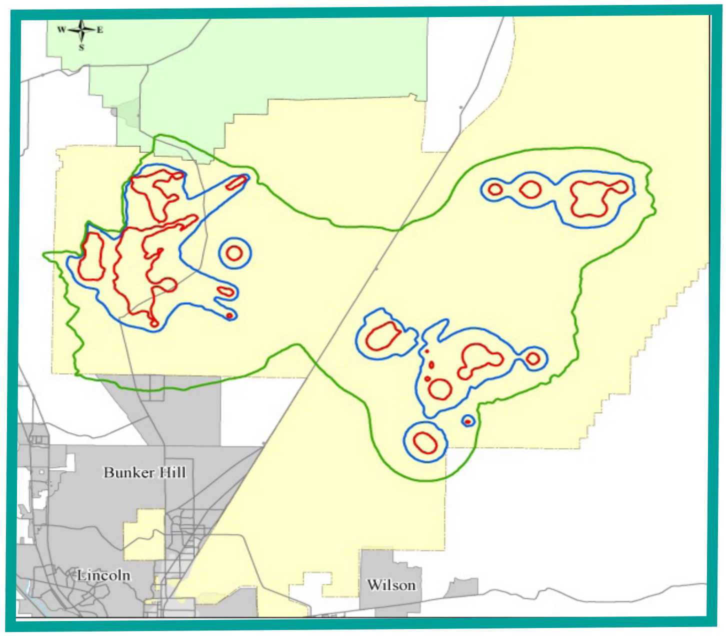
ESTCP
Cost and Performance Report

(SI-0006 Phase 2)



BNOISE2™ Noise Impact Software

June 2008

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

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COST & PERFORMANCE REPORT
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ACRONYMS AND ABBREVIATIONS

ACS	Army Claims Service
ACUB	Army Compatible Use Buffer
ADNL	A-weighted day-night average sound level
AMC	Army Materiel Command
ANSI	American National Standards Institute
AR	Army Regulation
BNOISE2	Blast Noise Version 2
BRAC	base realignment and closure
CDNL	C-weighted day-night average sound level
CERL	Construction Engineering Research Laboratory
CHABA	Committee on Hearing, Bioacoustics, and Biomechanics
DA PAM	Department of the Army Pamphlet
dB	decibel
DNL	day-night average sound level
DoD	Department of Defense
EA	Environmental Assessment
EIS	Environmental Impact Statement
EQT	Environmental Quality Technology
ERDC	Engineer Research and Development Center
ESTCP	Environmental Security Technology Certification Program
ETMP	Environmental Technology Plan
FICUN	Federal Interagency Committee on Urban Noise
FORSCOM	Forces Command
GIS	geographic information system
GUI	graphical user interface
IONMP	Installation Operational Noise Management Program
ISO	International Standards Organization
Leq	equivalent continuous noise level
LUPZ	land use planning zone
MCA	Military Construction, Army
MH	man hours
NEPA	National Environmental Policy Act
NMPlot	Noise Map Plot (software application)
NPV	net present value

ACRONYMS AND ABBREVIATIONS (continued)

ONMP	Operational Noise Management Plan
PK15(met)	peak level exceeded by 15% of all noise events “(met)” indicates that the variance is due to meteorology
PSPL	peak sound pressure level
R&D	Research and Development
SARNAM™	Small Arms Range Noise Assessment Model
SE	sound exposure
SEL	sound exposure level
TES	threatened and endangered species
TRADOC	Training and Doctrine Command
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine

ACKNOWLEDGEMENTS

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1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND

Weapons noise compromises the Department of Defense's (DoD) ability to maintain access to resources necessary for military training and testing. Community reactions to military noise include complaints, damage claims, legal action, political pressure, and other efforts to curtail the noisy activity. Noise concerns have prompted installations to relocate training, impose firing curfews (both time of day and day of the week), and close ranges. Such short-term-solution decisions, if made without reliable guidance by noise management technology, can needlessly hamper training mission capability and ultimately impact soldier proficiency and survival. Noise impact assessment software can guide planning decisions to minimize noise impacts on soldier and civilian health and welfare. Impulsive noise from military weapons training and testing is not governed by national laws; consequently, noise management consists of striking a balance between mission execution and environmental quality. Reliable guidance regarding noise level reduction under a wide range of conditions is arguably more critical than the absolute accuracy of noise level predictions.

The military noise impact assessment software, or noise model, known as Blast Noise Version 2 (BNOISE2™) enables assessment of high-energy impulsive noise impacts via calculation and display of noise contours for large arms, including explosive charges, artillery, armor, and missiles. The software was updated in the late 1990s, replacing the previous version known as MicroBNOISE.

BNOISE2™ is very useful as an environmental planning tool to address unwanted noise as an environmental attribute in the community. It can be used to avoid siting noise-sensitive land uses in regions of the adjacent community as well as to assess mitigation of environmental impacts of operational plans or new facilities. Implementation cost of this Army in-house-developed software consists essentially of learning to use the software, which is facilitated by expertise in acoustics and familiarity with military weapons systems.

1.2 OBJECTIVES OF THE DEMONSTRATION

The overall goal of this project was to validate and demonstrate the BNOISE2™ noise impact assessment software under typical conditions. The objective of the validation aspect of the project was to test the accuracy of BNOISE2™ by comparing calculation results with comprehensive noise monitor data to judge noise level prediction accuracy. The objective of the demonstration aspect of the project was to evaluate the software utility and cost during realistic noise management consultation.

1.3 REGULATORY DRIVERS

Department of the Army Pamphlet (DA PAM) 200-1 (2002) stipulates requirements and procedures for assessing training noise impacts. Noise contours are required for an Operational Noise Management Plan (ONMP) mandated by Army Regulation (AR) 200-1 version published in 1997 and revised in 2007. The National Environmental Policy Act (NEPA) requires assessment of impacts of proposed actions implemented by Department of the Army 32 Code of

Federal Regulations Part 651—Environmental Analysis of Army Actions, Final Rule. Noise is often one of the primary issues. A highly ranked Army Environmental Quality Technology (EQT) research and development (R&D) requirement, *Training and Testing Range Noise Control,* is a major requirement for this project. Another highly ranked Army EQT requirement, *Impact Protocols for Military Operations on Threatened and Endangered Species (TES)*, identifies noise as one of three impacts of particular concern. Regulatory drivers include the Endangered Species Act of 1973, as amended; the NEPA of 1970, as amended; the Sikes Act of 1995; and the Marine Mammal Protection Act. The software complies with applicable noise assessment practice promulgated by the American Nation Standards Institute (ANSI).

BNOISE2™ is optimally used as an environmental planning tool to address unwanted noise as an environmental attribute in the community at large, rather than a regulatory compliance tool, since there are no legally binding criteria for human exposure to noise that support compliance levels outside the facility perimeter. Calculated noise contours are used as planning tools for land use guidelines. BNOISE2™ can be used to avoid siting new noise-sensitive land uses in off-post areas impacted by military noise as well as to plan military facilities and operations to minimize community noise levels.

1.4 DEMONSTRATION RESULTS

This project had two primary aspects: validation and demonstration. The purpose of the validation aspect of the project was to test the accuracy of BNOISE2™ noise contour calculations. Each element of the application, particularly acoustical emission models and propagation calculation algorithms, had been validated under controlled conditions prior to the present project. This validation portion of this project was designed to evaluate the prediction accuracy of the software under actual conditions by measuring noise levels in the environs of a military training installation during an entire year, then comparing the measurements with BNOISE2™ predictions; the performance goal was agreement within 5 dB. The validation effort was unfortunately not fully successful. After noise monitoring was complete, it was discovered that the microprocessor-based Norsonics™[1] 121 noise monitors incorrectly calculated the noise level metrics that researchers planned to use for comparison with BNOISE2™ predictions. Accurate values of ⅓-octave-band spectrum unweighted sound exposure level (SEL) for each event had been recorded, from which the needed metric values could be calculated, though only at considerable cost. A lack of reliable data regarding the firing that occurred during noise monitoring further hampered the validation effort. Project researchers and ESTCP officials agreed to not devote substantial additional resources to analysis of the field validation data. The experience of the validation effort provided valuable insight regarding how best to employ the software, and also guided evolution of improved impact assessment methodology for high-energy impulsive noise, as described in Section 6 of this report. Experience gained during the attempted validation, along with concurrent noise consultation experiences, culminated to convince the research team that average-noise protocols do not adequately assess blast noise impacts. This project was a major influence that led to a change in the way the Army assesses blast noise, so it was by no means unsuccessful. This project will have significance well beyond demonstration and validation of the noise models. It was the first comprehensive and objective

[1] Citing product or company names does not constitute endorsement by ERDC/CERL, USACHPPM, ESTCP, Strategic Environmental Research and Development Program (SERDP), or the U.S. Army.

evaluation of several aspects of correlation between noise impact assessment procedures and actual installation activity. It will help to shape more effective noise impact management procedures and tools for the future.

The demonstration aspect of the project evaluated the performance and cost of BNOISE2™ in assessing and mitigating the impact of additional noise due to increased operations associated with Army Modular Force Transformation restationing. Evaluation of various training scenarios and range siting options enabled impact assessment and identification of mitigation options that without BNOISE2™ could not have been accomplished quickly enough to meet the NEPA document preparation schedule. BNOISE2™ was shown to reduce the labor and cost of noise analysis by at least 67%, substantially exceeding the 20% goal. This improved efficiency enables USACHPPM to accomplish many more noise consultations each year. Additional substantial cost savings are realized as a result of effective management of noise emission from training and testing ranges. The software is very useful in determining the effects of changes in facilities and operations; these effects are valid regardless of uncertainties and ephemeral conditions.

1.5 STAKEHOLDER/END-USER ISSUES

The primary end user is the USACHPPM Operational Noise Program, which provides blast noise consultation to all of DoD for both large and small arms. Other users include private sector consultants who perform noise assessments for installations. All are concerned about software accuracy, implementation cost, cost savings, and ease of use. The U.S. Army developed BNOISE2™ in-house at the ERDC/CERL, so there are no proprietary considerations. Implementation cost consists essentially of learning to use the software, which is facilitated by familiarity with acoustical principles and military weapons and training practices.

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

The BNOISE2™ software package enables calculation and display of noise contours for the full suite of large arms, including explosives, artillery, armor, and missiles. The original version of the noise model was developed in the 1970s as a mainframe computer program to calculate noise contours for large guns. It was later adapted to run on desktop computers and renamed MicroBNOISE. The model was extensively updated and renamed BNOISE2™ in the late 1990s. Improvements included:

- A graphical user interface (GUI) to replace the text editor for data input
- The capability to calculate supersonic projectile sonic boom noise
- Addition of several noise metric and assessment protocol options
- Several additional weather (propagation) options
- Addition of algorithms to account for the effect of diffraction around terrain features and over-water propagation
- An expanded selection of weapons, including a wide variety of explosives.

The architecture of BNOISE2™ is shown in Figure 1. The software consists of three program modules: the GUI, the DOCALC calculation engine, and the Noise Map Plot (NMPlot) contour display application. The information that the user enters via the GUI is written to a case file and handed to the calculation engine. The data calculated by the engine is written to the NMBGF file and handed to NMPlot for fitting and display of noise contours.

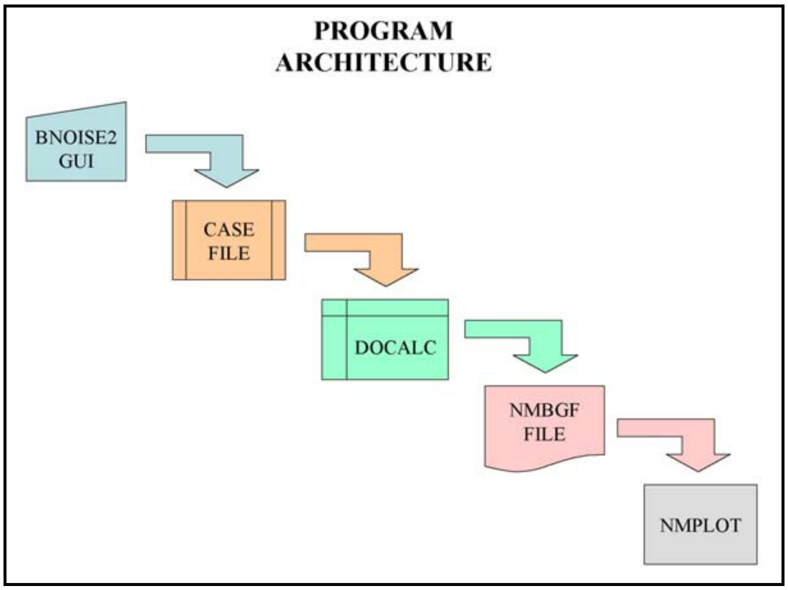

Figure 1. BNOISE2™ Architecture and Process Diagram.

BNOISE2™ requires input data regarding type of weapon and ammunition, number and time (day or night) of rounds fired, and range, firing area, and impact area attributes such as location

and size. BNOISE2™ offers a choice of a variety of sound exposure metrics, frequency weightings, and assessment procedures for large arms noise (Committee on Hearing, Bioacoustics, and Biomechanics [CHABA], 1981; CHABA, 1996; ANSI S12.9 Pt. 4, 2005). The model accounts for spectrum and directivity as well as emitted acoustical energy of muzzle blast (Pater, 1981), projectile detonation, and projectile sonic boom associated with firing large arms, which facilitates accurate sound level prediction and interpretation of receiver response. Accurate acoustical energy emission parameter values (source models) are based on empirical data. BNOISE2™ features a point-and-click GUI, pull down menus, and on-line help—all designed to maximize user productivity.

U.S. Army weapons are powerful sources of impulsive acoustical energy; emitted noise can travel to distances of tens of kilometers. Atmospheric conditions profoundly affect long-range sound propagation (Schomer and Luz, 1978). The sound level can vary by more than 50 decibels (dB) due to changes in weather, in particular vertical profiles of temperature and wind velocity. Such a change is extremely significant; a 10-dB change represents roughly a doubling in subjective loudness for many types of noise (Crocker, 1998). BNOISE2™ accounts for these effects statistically so that noise impacts can be assessed or forecast in situations when the weather is known only in terms of climatological expectations.

2.2 PROCESS DESCRIPTION

The demonstration aspect of the project evaluated the utility of BNOISE2™ in dealing with realistic installation noise management problems under operational conditions. The software was used for NEPA assessment of noise impacts for several proposed scenarios involving increased training operations activity.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

Considerable testing of the software elements occurred before this current validation and demonstration project. The assessment procedures, metrics, and frequency weightings follow ANSI standards (ANSI S1.1, 2004; ANSI S1.4, 2001; ANSI S12.9 Pt.1, 2003; ANSI S12.9 Pt. 4, 2005). The software uses as the starting point for noise level predictions an acoustical emission (source) model that is based on careful measurements for each weapon (Pater, 1981, and unpublished data). The propagation algorithms that are used to predict noise levels (Gilbert and White, 1989; White and Gilbert, 1989; Li et al., 1994; White and Li, 1996) were verified by comparison with experimental data under known atmospheric propagation conditions (White, 1994). The current project was designed to test BNOISE2™ under realistic, uncontrolled conditions that are encountered in typical noise management efforts at installations.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

BNOISE2™ enables assessment of explosive and large arms range noise. The capability to quickly produce noise contours and to evaluate alternative noise mitigation strategies is highly useful as effective support of an environmental planning process as required by AR 200-1 (2007). Given the always-present uncertainties in propagation conditions and operation parameters (e.g., weapon, location, number of shots) that strongly influence sound level predictions, good agreement between predictions and spot measurements is not a reasonable

expectation. Accuracy of predicted sound level ultimately depends not only on accurate source models and propagation algorithms, but also on accurate knowledge of actual sound speed profile, type and location of weapon, and number of shots. For large arms, very few mitigation means are available (Pater, 1979; Pater et al., 1981a; Pater et al., 1981b; Pater and Shea, 1984) beyond range siting (Pater, 1981) and avoiding unfavorable weather conditions. The software is most effective for reliable determination of the effects of changes in operations or facility location and design and provides extremely useful noise impact management guidance regardless of uncertainties regarding past or future weather or training throughput details.

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3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

The overall goal of this project was to validate and demonstrate the BNOISE2™ noise impact assessment software. The objective of the validation aspect of the project was to test the accuracy of BNOISE2™ by comparing calculation results with comprehensive noise monitor data to judge noise level prediction accuracy. The validation effort is summarized in Section 1.4.

The objective of the demonstration aspect of the project was to evaluate the noise model utility and cost during realistic noise management consultation. Sections 3, 4, and 5 of this report are devoted to a detailed description of the demonstration effort. Demonstration performance measures were the amount of noise dose reduction that was identified by using the software, the cost of use, and the cost savings. These were determined by USACHPPM and installation personnel during NEPA analysis by using the software to predict noise contours and assess noise impacts associated with several scenarios for increased range activity due to relocation of Army brigades.

3.2 SELECTING TEST SITES/FACILITIES

The demonstration site example is an actual assessment that was carried out by USACHPPM, chosen because it illustrates a typical noise impact assessment for large weapons. This site is a major military training facility that will be referred to by the pseudonym “Fort Fraser” to comply with installation directives regarding facility and operational security.

3.3 TEST FACILITY HISTORY/CHARACTERISTICS

Demonstration of BNOISE2™ was carried out in conjunction with the proposed increased activity at Fort Fraser. Specific distinguishing features of the installation and surrounding population distribution, particularly details of range location and function, have been modified at the installation’s request to avoid compromising facility and operational security. The features shown in Figure 2 are faithful to the situation for purposes of demonstrating the use of BNOISE2™ to achieve noise reduction. The facility is typical of many large installations in that it has been a major training facility for more than 50 years. It was initially located in a sparsely populated region, but communities grew up nearby to serve the needs of the installation. As they grew, they became less economically dependent on the installation. Increasing awareness of environmental quality led to a population less tolerant of the noise that is implicit in the operation of a combat training facility.

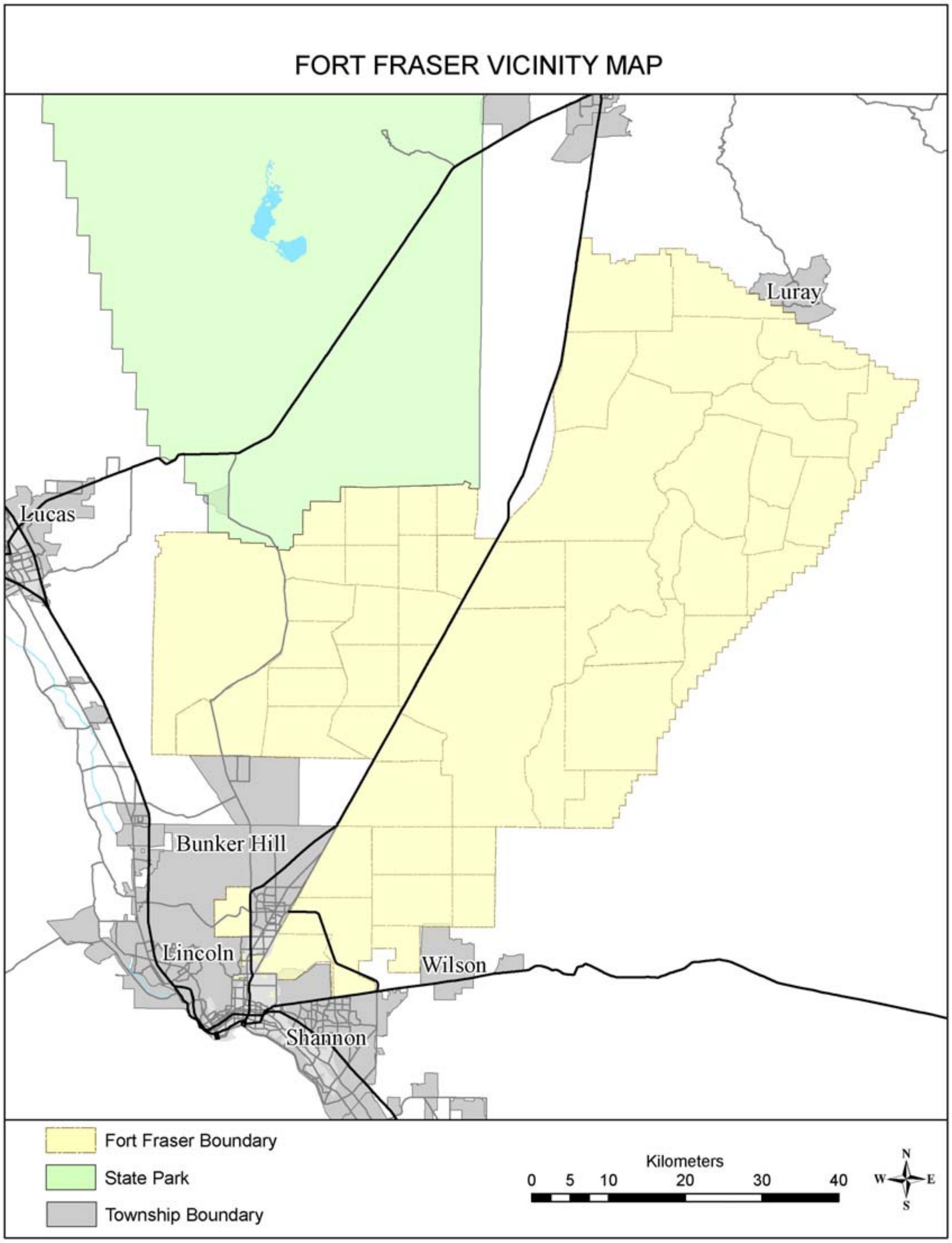


Figure 2. Fort Fraser Vicinity Map.

4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA FOR THE "FORT FRASER" DEMONSTRATION

The BNOISE2™ software application was used in evaluating the impact of proposed increased operations at Fort Fraser. The actual name of the installation and actual map features are not used in this demonstration description to avoid revealing facility information that might compromise operational security. The presentation is faithful to meaningful illustration of the noise analysis and results; it serves to demonstrate the time and cost saving benefits of BNOISE2™ and the degree of change in the noise environment that can be identified.

Noise impact assessment, as the basis for recommendations for reducing identified impacts, was carried out according to DoD land use and compatibility principles and guidelines. In 1980 the Federal Interagency Committee on Urban Noise (FICUN, 1980) developed land use guidelines, which were adopted by the DoD, for areas on and/or near noise producing activities such as highways, airports, and firing ranges. The Army's Operational Noise Management Program (ONMP), mandated by Army Regulation AR 200-1 (2007), designates noise zones for land use planning, which are presented in Table 1. Projecting these zones onto an area map can help planners develop compatible land uses and reduce noise impacts. The borders of the zones are defined by noise level contours of specific values. Noise level contours should be viewed as indications of the local noise environment, not as the boundary between acceptable and unacceptable noise levels; stepping across the location on the ground of a noise contour does not result in a sudden change in the noise environment. The guidelines, expressed in terms of long-term average noise exposure levels ADNL (A-weighted day-night average sound level) and CDNL (C-weighted day-night average sound level), are based on a significant body of research results (CHABA, 1981; CHABA, 1996). The guidelines are consistent with the methodology and guidance that is accepted practice for other types of noise such as transportation noise due to aircraft and highway traffic (Schultz, 1978).

Table 1. Noise Limits for Noise Zones
(AR 200-1, 2007).

Noise Zone (See Appendix A)	Noise Limits (dB)		
	Aviation ADNL	Impulsive CDNL	Small Arms PK15 (met)
LUPZ	60 – 65	57 – 62	n/a
I	< 65	< 62	< 87
II	65 – 75	62 – 70	87 – 104
III	> 75	> 70	> 104

dB = decibel
LUPZ = land use planning zone
ADNL = A-weighted day-night average sound level
CDNL = C-weighted day-night average sound level
PK15(met) = single event peak level exceeded by 15% of events
n/a = not applicable

Weapon impulse noise varies widely due to weather (Schomer and Luz, 1978). Time-averaged noise metrics such as CDNL can be usefully supplemented by single event metrics to more accurately characterize community noise impact, particularly regarding the likelihood of receiving noise complaints (Pater, 1976; Hede and Bullen, 1982; Luz et al., 1983; O'Loughlin et

al., 1986; Sorenson and Magnusson, 1979). However, simply quoting the expected mean value of a single event metric does not convey the range of expected noise levels or the degree of risk of adverse community reaction such as noise complaints. A new single event noise metric, PK15(met), was developed that takes into account the statistical variation in received weapons noise level. This is the peak level that statistically is expected to be exceeded by about 15% of all noise events. The "(met)" indicates that the variance is due to meteorology. Noise event levels would be expected to be below the PK15(met) value for about 85% of all occurrences. This gives the installation and the community a more realistic means to consider the degree of noise impact in a particular area in terms of noise that will actually be heard rather than an average level of infrequent highly variable noise events. Information regarding the degree of complaint risk as a function of PK15(met) noise metric values is presented in Table 2.

Table 2. Risk of Noise Complaints by Level of Noise
(AR 200-1, 2007).

Risk of Noise Complaints	Large Caliber Weapons Noise Limits (dB) PK15(met)
Low	< 115
Medium	115 – 130
High	> 130
Risk of physiological damage to unprotected human ears and structural damage claims	> 140

dB = decibel
PK15(met) = Single event peak level exceeded by 15% of events

In support of Army Modular Force Transformation and Base Realignment and Closure (BRAC), USACHPPM was tasked to provide Fort Fraser with large caliber weapons noise contours required for an Environmental Impact Statement. Proposed actions included stationing of up to six additional brigades, which would require up to seven major new ranges and 140 artillery and mortar firing points. The BNOISE2™ noise model was used to generate noise contour maps for five alternative scenarios of additional brigade activity to provide guidance for assessing the relative noise impacts of the scenarios, including new ranges and firing points that would be needed.

A total of five cases were considered; the time-averaged CDNL noise contours for each case are presented as follows:

- Figure 3—existing operations at Fort Fraser
- Figure 4—existing operations plus 1 additional brigade
- Figure 5—existing operations plus 3 additional brigades
- Figure 6—existing operations plus 4 additional brigades
- Figure 7—existing operations plus 6 additional brigades

Assessments were also conducted in terms of the single event statistical metric PK15(met) to assess change in complaint risk. Neither the event duration nor the number of events affects the magnitude of the PK15(met) metric, so the size of the contours remains the same regardless of the number of events.

- Figure 8 presents PK15(met) metric contours for existing operations.
- Figure 9 presents PK15(met) metric contours for existing operations plus the additional brigade activity, including all the proposed new ranges.

4.2 PERFORMANCE CRITERIA

Demonstration performance measures for this project were specified in terms of the utility of community noise exposure predictions and the cost of obtaining them. Quantifiable performance objectives for this project are as follows:

1. Ability to identify a 20% change in community noise exposure in siting training activities
2. Enable a 20% reduction in overall cost associated with noise impact assessment.

The ability to identify a 20% change in community noise exposure is not a clear specification; this goal can be clarified and more appropriately specified as follows. A change of 20% in sound exposure (SE) is a change in SEL of only 1 dB, which would probably be judged to be an insignificant change in the noise environment. An SEL change of 10 dB is judged by humans to be about a factor of two change in perceived noise level (Crocker, 1998). This implies that a 20% change in subjective noise exposure is equivalent to an SEL change of about 3 dB. While a 3 dB change in noise level can be significant, a 4- or 5-dB reduction in SEL or day-night average sound level (DNL) is a traditional goal for a noise level reduction that is unarguably significant in terms of human perception of noise exposure.

4.3 DATA ASSESSMENT

Examination of the data presented in Figures 3 through 9 resulted in the following conclusions regarding the noise environment around Fort Fraser.

- Figure 3 shows the CDNL time-average noise contours for existing operations at Fort Fraser. The LUPZ 57-dB CDNL contour extends off-post at the northern, southern, and southeastern boundaries of Fort Fraser. According to the land use guidelines presented in Table 1, the existing land uses within the LUPZ noise contour are acceptable.

- Figure 4 shows the CDNL contours for existing operations and one additional brigade. The LUPZ 57-dB CDNL contour extends further off-post at the northern and southern boundaries of Fort Fraser, with little change at the southeastern boundary. In the city of Bunker Hill, the CDNL will increase by about 3 dB. In the city of Wilson, the CDNL does not change significantly. According to the land use guidelines in Table 1, the existing land uses in the LUPZ noise contour are acceptable.

- Figure 5 shows the CDNL contours for existing operations and three additional brigades. The LUPZ 57-dB CDNL contours extend still further off-post at the northern and southern boundaries of Fort Fraser. The normally not recommended

Noise Zone II contour extends beyond the southern boundary of Fort Fraser into the community of Bunker Hill. The CDNL level in Bunker Hill increases by about 2 dB relative to one additional brigade and by about 5 dB relative to existing operations. There is a small increase of about 1 or 2 dB in the city of Wilson, but the levels are low.

- Figure 6 shows the CDNL contours for existing operations and four additional brigades. The LUPZ 57-dB CDNL and Zone II contours extend somewhat further beyond the northern and southern boundaries of Fort Fraser. The CDNL levels in Bunker Hill increase by about an additional 1 dB, for a total increase of about 6 dB over existing operations. There is little additional change at the southeastern boundary or in the city of Wilson.

- Figure 7 shows the CDNL contours for existing operations and six additional brigades. The LUPZ 57-dB CDNL and Zone II contours extend still further beyond the northern and southern boundaries of Fort Fraser and into Bunker Hill. The CDNL change in Bunker Hill amounts to about a 7-dB increase relative to existing operations. There is a small additional increase of about 1 or 2 dB at the southeastern boundary and in Wilson.

- Figure 8 presents the PK15(met) contours for existing operations. The 115-dB minimal complaint risk contour just touches the southern boundary and extends just beyond the southeastern boundary. The 130-dB high risk of complaint contour does not extend beyond the boundary.

- Figure 9 presents the PK15(met) contours for existing operations and the additional brigade activity, including all the proposed new ranges. The number of events does not affect the magnitude of the PK15(met) metric, so the size of the contours remains the same regardless of the number of events. The 115-dB minimal risk of complaint contour does not change at the southern boundary in the vicinity of the city of Bunker Hill, but it extends a considerable distance beyond the southeastern boundary toward the city of Wilson. The 130-dB high risk of complaint contour extends slightly beyond the southeastern boundary into an area that is not developed at this time. The PK15(met) metric values increase by about 5 dB in the city of Wilson and by a smaller margin in the city of Bunker Hill, relative to existing operations. In both cases, the predicted PK15(met) values in both cities are well below the 115-dB threshold at which complaints are expected.

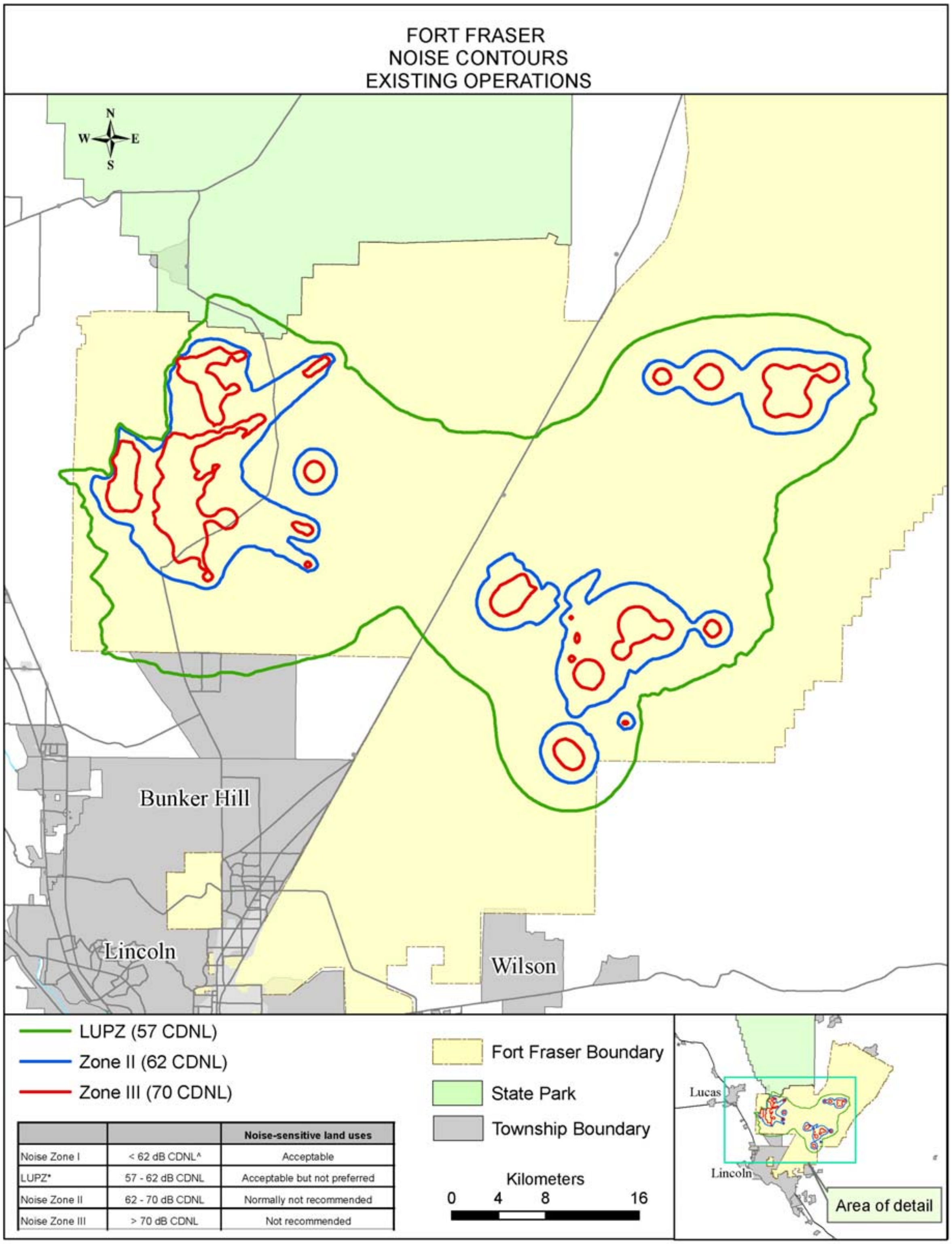
In summary, the maximum increase in CDNL is about 7 dB in Bunker Hill and about 3-dB (a barely significant increase) in Wilson, for any of the scenarios. Conversely, the increase in PK15(met) is about 5-dB in Wilson and only 2- or 3-dB in Bunker Hill. These changes are consistent with increased current activity concentrated in the region of Fort Fraser which lies to the north of Bunker Hill, along with new, larger weapons concentrated in the southeastern portion of the installation. Using both metrics, it can be concluded that while the CDNL level in Bunker Hill is at a level that might indicate concern, the PK15(met) levels in Bunker Hill are

well below the 115-dB threshold for complaints, so the increased number of events and CDNL level are not likely to be of consequence. In Wilson, both the CDNL and the PK15(met) levels are well below the thresholds for concern. The PK15(met) values depend on the weapon type and location, without the uncertainty in number of rounds fired that strongly influences the value of CDNL.

A noise model is often of great value to identify changes in facility design or operation that offer means to mitigate the noise environment. The above case illustrates a somewhat different use, in which increases in noise level that occur due to changes in facilities and operations are quantified. The significance and possible consequences of the noise increase are then evaluated to provide decision guidance. In this case, even though significant changes in noise level were predicted, it could be shown that the levels are not likely to cause a problem.

4.4 TECHNOLOGY COMPARISON

Two comparisons can be made to evaluate BNOISE2™ relative to other technology. Before BNOISE2™, USACHPPM used MicroBNOISE to perform large arms noise assessments and consultations, which required laborious data entry via a text editor and hand preparation of contour displays, and offered only the CDNL metric. Because MicroBNOISE was not generally available, other entities could perform large arms assessments only by some combination of hand calculations and field monitoring. The BNOISE2™ software allows for the conceptual relocation of ranges and the assessment of various stationing scenarios with relative ease. BNOISE2™ is available to assess blast noise from military weapons and provides valuable noise management and mitigation guidance.



		Noise-sensitive land uses
Noise Zone I	< 62 dB CDNL^	Acceptable
LUPZ*	57 - 62 dB CDNL	Acceptable but not preferred
Noise Zone II	62 - 70 dB CDNL	Normally not recommended
Noise Zone III	> 70 dB CDNL	Not recommended

Figure 3. CDNL Contours for Existing Operations.

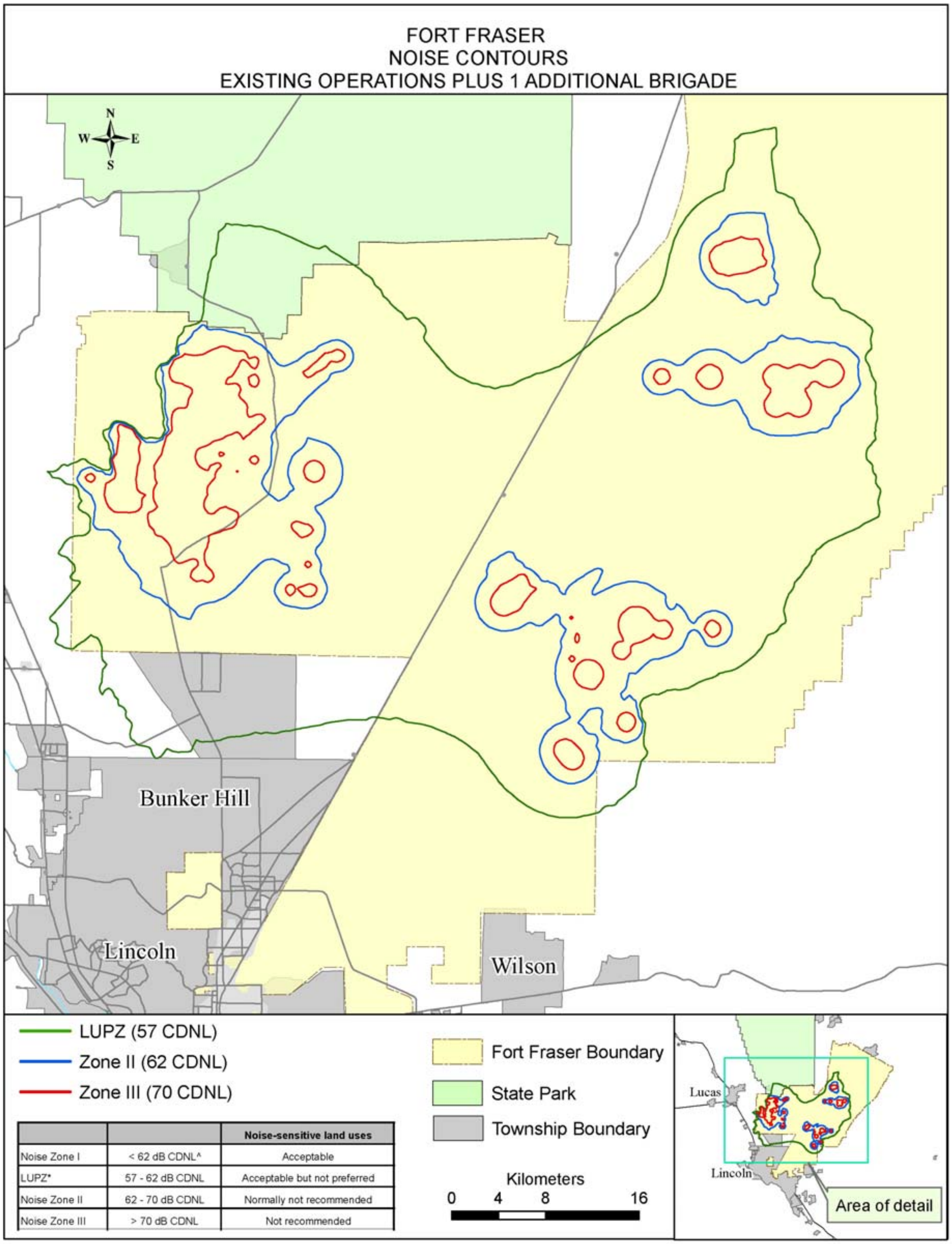
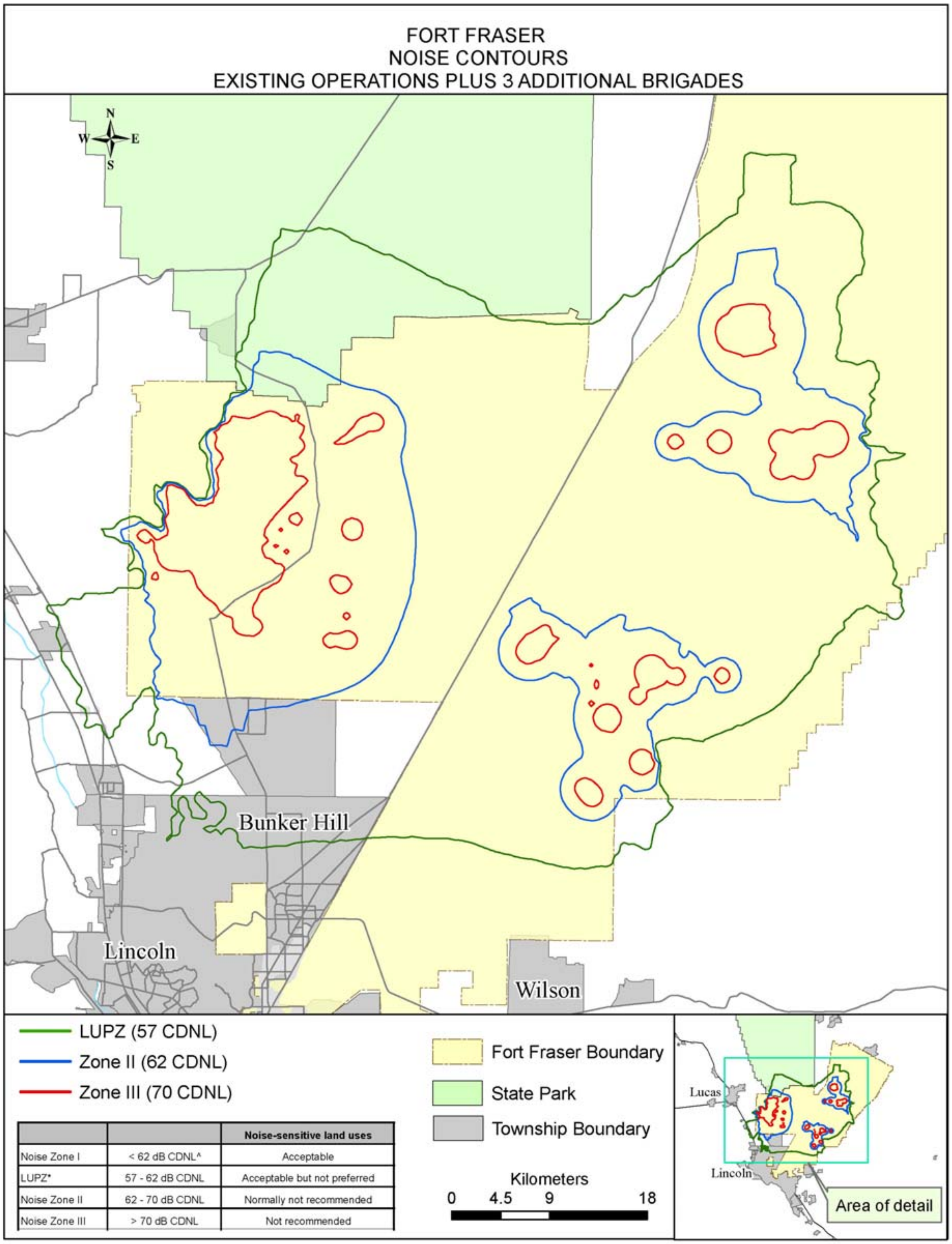
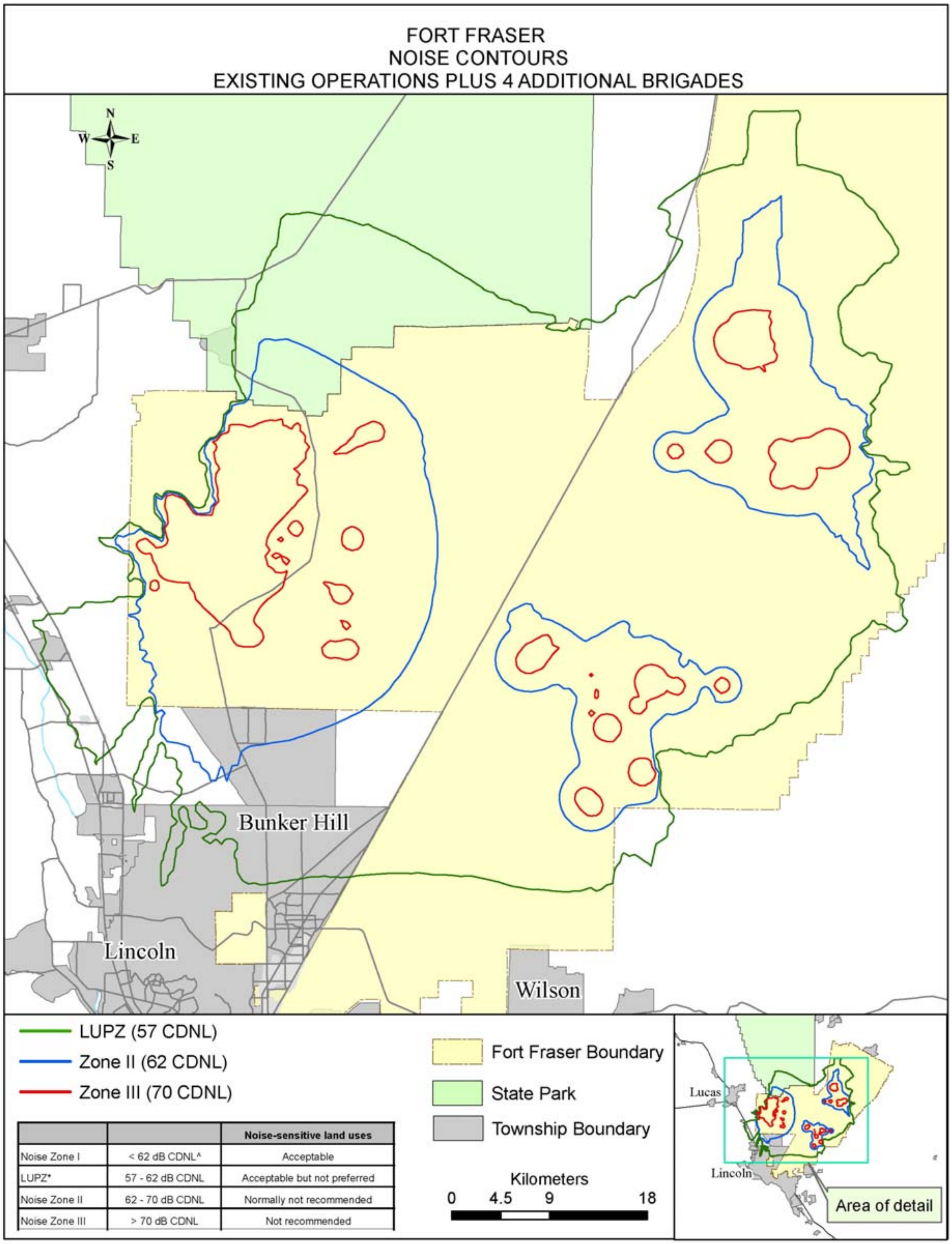


Figure 4. CDNL Contours for Existing Operations and One Additional Brigade.



		Noise-sensitive land uses
Noise Zone I	< 62 dB CDNL^	Acceptable
LUPZ*	57 - 62 dB CDNL	Acceptable but not preferred
Noise Zone II	62 - 70 dB CDNL	Normally not recommended
Noise Zone III	> 70 dB CDNL	Not recommended

Figure 5. CDNL Contours for Existing Operations and Three Additional Brigades.



		Noise-sensitive land uses
Noise Zone I	< 62 dB CDNL^	Acceptable
LUPZ*	57 - 62 dB CDNL	Acceptable but not preferred
Noise Zone II	62 - 70 dB CDNL	Normally not recommended
Noise Zone III	> 70 dB CDNL	Not recommended

Figure 6. CDNL Contours for Existing Operations and Four Additional Brigades.

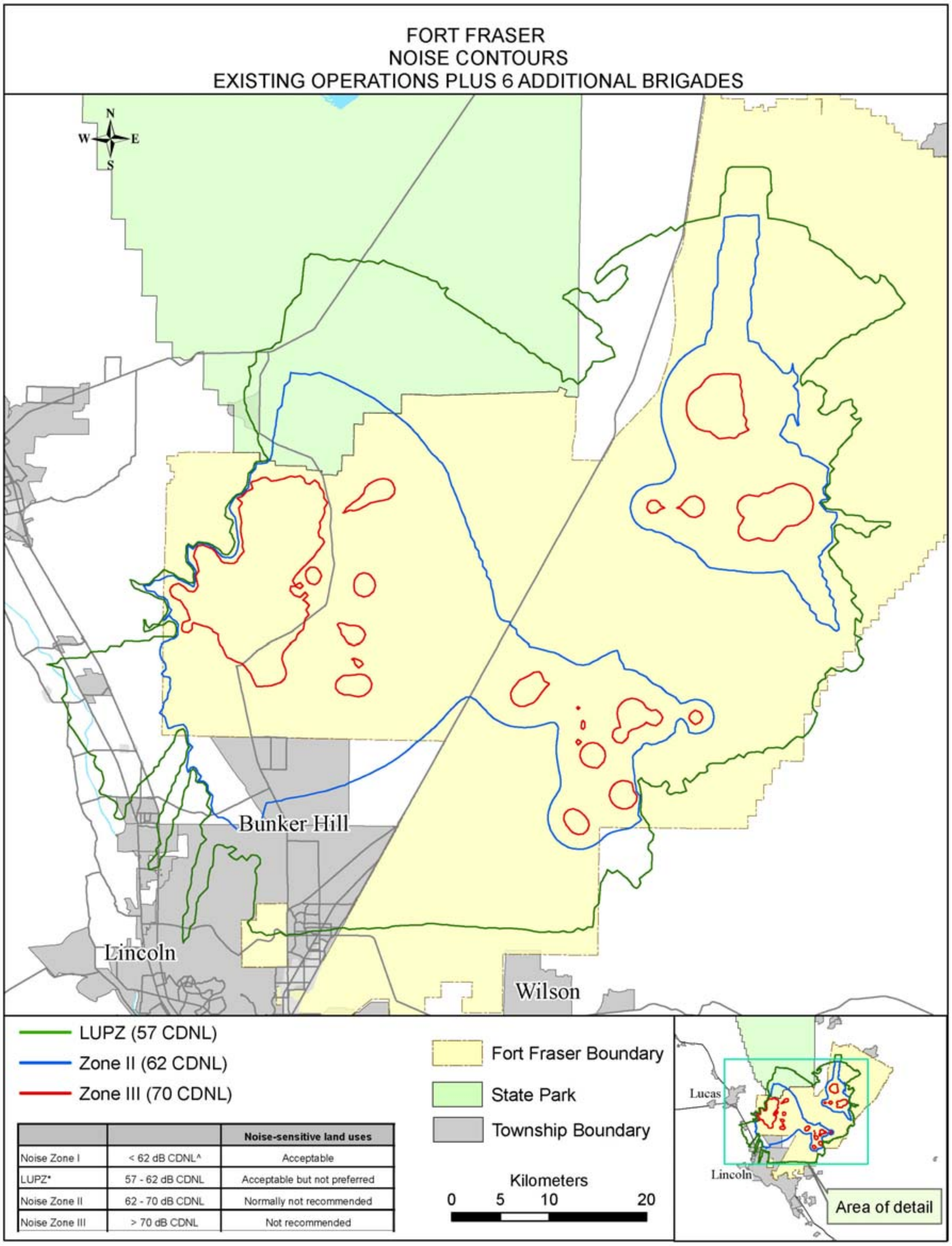


Figure 7. CDNL Contours for Existing Operations and Six Additional Brigades.

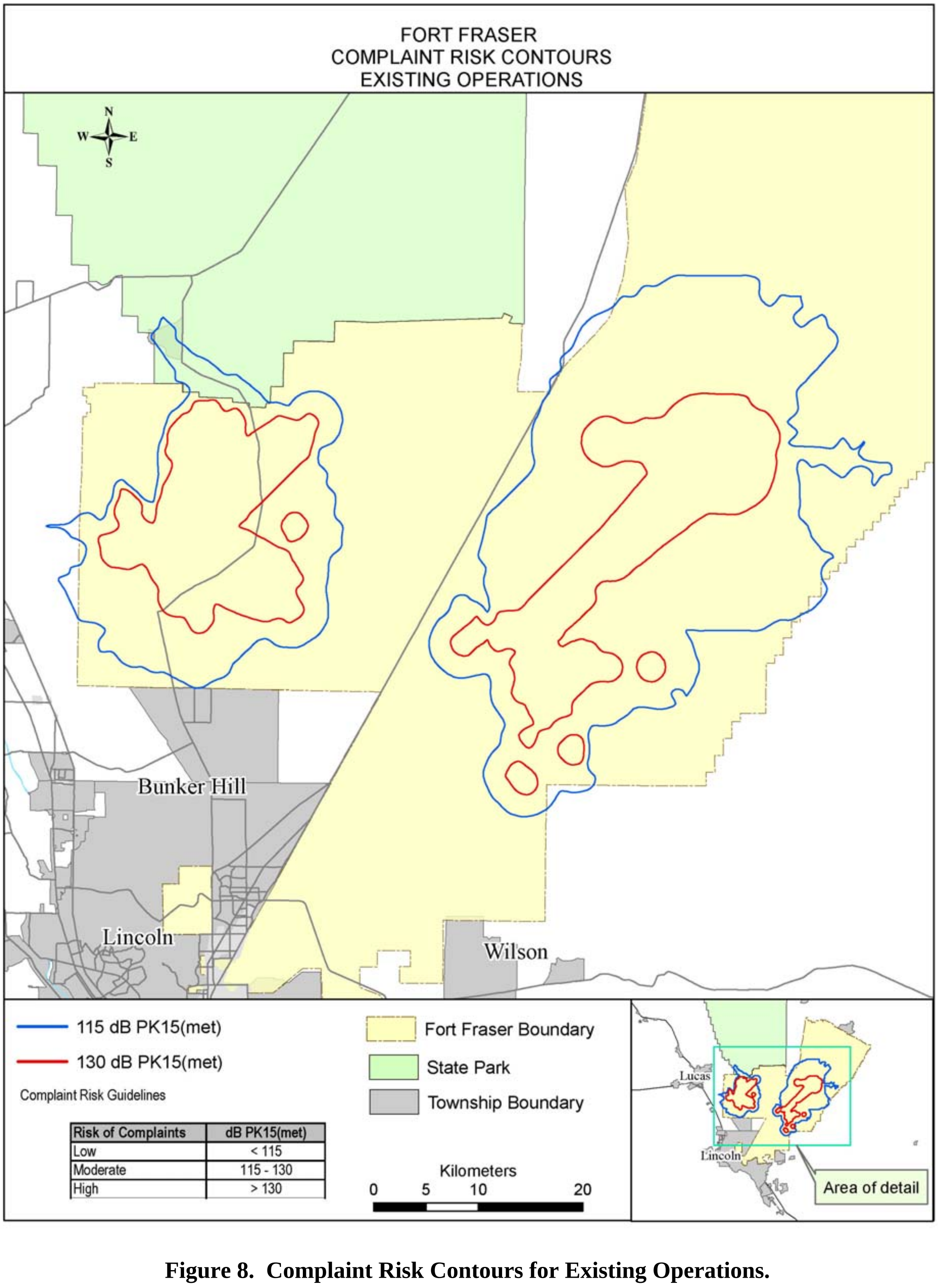


Figure 8. Complaint Risk Contours for Existing Operations.

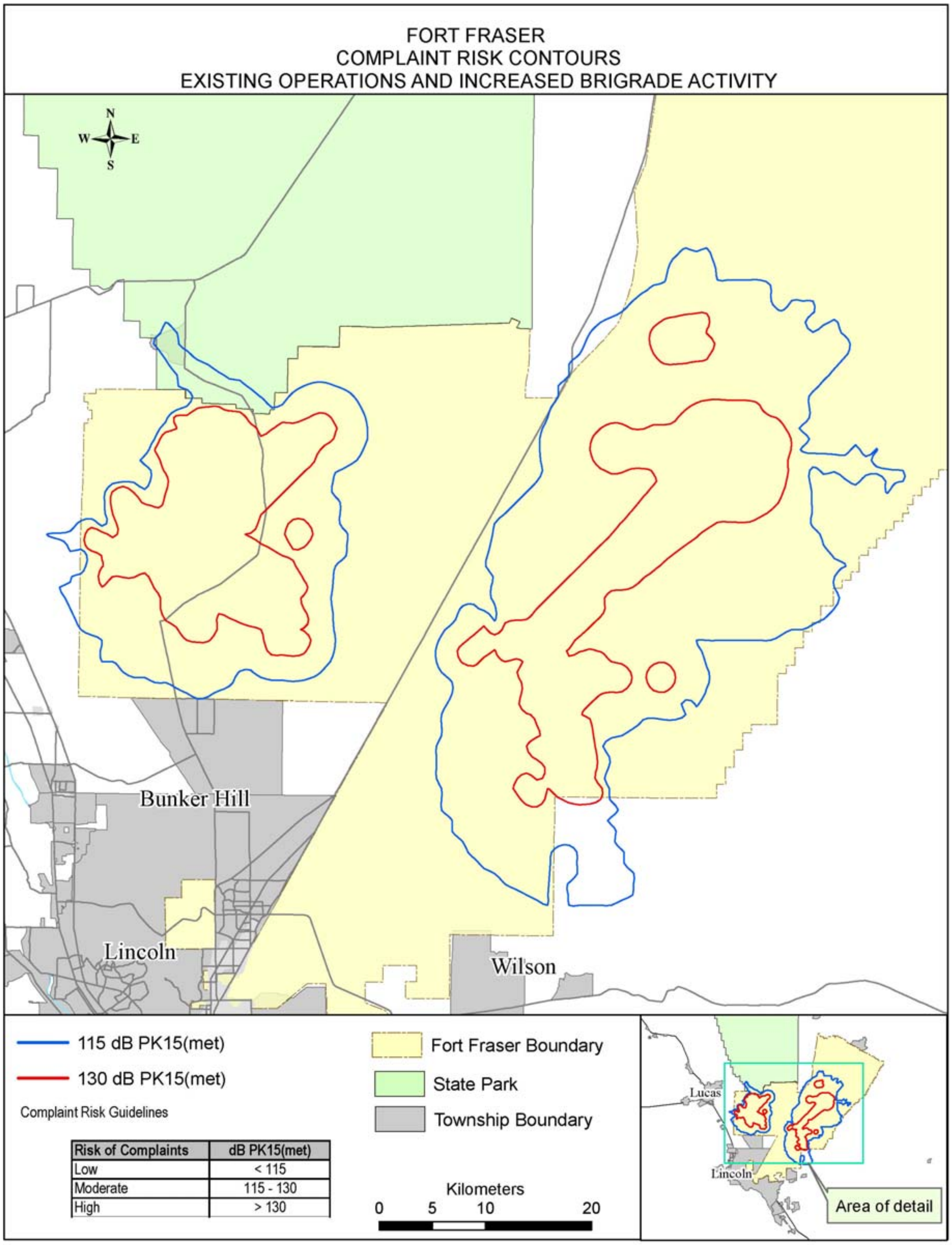


Figure 9. Complaint Risk Contours for Existing Operations and Additional Brigade Activity.

5.0 COST ASSESSMENT

5.1 COST REPORTING

A quantifiable performance objective of the noise model demonstration is a 20% reduction in overall cost of using the BNOISE2™ software. One consideration is the startup cost of using the BNOISE™ noise software. Another is the cost of using BNOISE™ to perform a noise assessment compared with the cost of using previous methods. Still another consideration is the savings that result from operating a range complex according to recommendations that result from BNOISE2™ analysis compared with the costs of operating without benefit of noise software guidance.

The startup costs associated with using noise software to guide noise management are small. They consist of the cost of an ordinary personal computer, if a suitable one is not already available, and the cost of training the user to use the software. Assuming that the user is familiar with training procedures and the weapons of interest and has some acoustics knowledge, the training and familiarization is about 40 hr of labor per user, usually less than $4,000 per user. The BNOISE2™ software is provided free of charge.

The costs of performing a noise assessment at an installation, at USACHPPM or at a contractor's site will depend on how extensive the required noise impact analysis is; costs can range from nearly zero to as much as $100,000. The cost picture may also include considerations of USACHPPM mission funding leveraging and of private contractors' additional costs of profit. Much of the cost of an assessment is in obtaining and validating the training data that constitutes the input data for the assessment.

Operating cost considerations include damage claims, range closures, land acquisition costs, costs due to loss of training days and training acres, and noise complaints. An example of lost training and lost construction funds is the deactivation of a new multimillion dollar small arms range that was sited without a noise assessment and was abandoned and rebuilt in another location because of adverse community reaction to noise. An estimate of the cost to the Army of training and testing noise, and what cost reduction can be realized through a noise management program based on technology and public outreach is presented in Appendix B. The overall cost of noise to the Army is very large but was not included in the cost assessment in this report because such costs are difficult to evaluate conclusively. Such large cost savings, along with the desire to preserve mission capability and to be a good neighbor, motivate installations to perform noise impact analysis using the BNOISE2™ noise software.

5.2 COST ANALYSIS

The cost analysis presented in Table 3 is based on the NEPA noise impact assessment carried out by USACHPPM for Fort Fraser using BNOISE2™. Two cost savings analyses were performed and are reported. One was based on a comparison with using the previous version of the noise simulation software MicroBNOISE. A second was performed based on hand calculations and on-site monitoring would apply to users for whom MicroBNOISE was not available.

Table 3. Cost Comparison – Noise Assessment for Proposed Increased Activity.

Previous Method—On-site Noise Monitoring Conducted over a 1-Year Period*		
	Labor cost	**Man hours**
Preliminary hand calculation of noise levels by project officer	$22,270	300
Equipment maintenance/preparation by technicians	$20,800	640
Equipment supplies and shipping	$3652	n/a
On-site monitoring labor:		960
Project officer	$23,632	
Technicians	$20,800	
Data analysis by project officer	$23,632	320
Report		
Project officer	$11,826	160
Senior project officer	$7,120	80
Admin	$1,968	60
Previous Method—On-site Noise Monitoring Total Cost	$135,700	2,520
**Cost analysis is based on four 2-week, on-site monitoring studies with one project officer and two technicians. This figure does not include travel expenses, i.e. airfare, hotel, per deim, rental vehicle.*		
Previous Method --- MicroBNOISE	**Labor cost**	**Man hours**
Noise assessment via MicroBNOISE	$39,656	480
Report:		
Project officer	$3,305	40
Senior project officer	$1,780	20
Admin	$492	15
Previous Method—MicroBNOISE Total Cost	$45,233	555
Demonstration Method --- BNOISE2™	**Labor cost**	**Man hours**
Noise assessment via BNOISE2™	$9,914	120
Report:		
Project officer	$3,305	40
Senior project officer	$1,780	20
Admin	$492	15
Demonstration Method—BNOISE2™ Total Cost	$15,491	195
	Labor Cost Savings	**Man Hour Savings**
BNOISE2™ Cost Savings versus On-Site Noise Monitoring	$120,209	2,325
	89%	92%
BNOISE2™ Cost Savings versus MicroBNOISE	$29,742	360
	78%	65%

5.3 COST COMPARISON

The cost comparison presented in Table 3 indicates that the cost benefits of using BNOISE2™ to perform a specific noise assessment of a proposed activity increase versus the previous methods of MicroBNOISE or on-site monitoring and hand calculations. The cost of the BNOISE2™ noise impact assessment was $15,491 and required 195 man-hours (mh), as detailed in the lower portion of Table 3.

The Fort Fraser project using the previous version of the software MicroBNOISE would have taken approximately 5 months to carry out, at a cost of $45,233 and 555 mh. Utilizing the MicroBNOISE software was time consuming. Data entry on average took twice as long as BNOISE2™. The results from MicroBNOISE were not geographic information system (GIS)-compatible; they were output from the software in tabular form, and each scenario was hand drawn on a military topographic map.

Before computerized noise models became available, a noise impact assessment for explosions and/or large arms ranges was typically carried out by hand calculation of received noise, in conjunction with conducting a minimum 2-week, on-site monitoring study, followed by approximately 2 weeks for monitoring data analysis and 1 week for report writing. The monitoring study would have to be performed a minimum of four times per year to sample all weather conditions. The Fort Fraser project, conducted over 1 year, would have cost a minimum of $135,000 and at least 2,500 mh.

The use of BNOISE2™ reduced the cost by approximately $30,000 to $120,000, and reduced labor by 360 mh to 2,325. This cost reduction amounts to between 67% and 89%, which easily meets the 20% cost reduction goal. Such savings allow USACHPPM to provide faster, more cost-effective service to DoD.

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6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

BNOISE2™ reduces the resources needed to predict the levels of noise emitted from existing and proposed ranges throughout DoD, including the statistical variance of event noise. It also enables determination of the change in noise environment resulting from changes in facilities and/or operations, independent of uncertainties in weather effects and operation parameters that influence the actual noise level. The software is free, and the cost of implementation is minimal, requiring only an ordinary computer and familiarization with the software. Optimal utilization of the software is facilitated by expertise in acoustics and military weapons systems. BNOISE2™ enables reasonable delivery time and cost to evaluate noise impacts and examine alternative scenarios for both testing and training range operations. This improved efficiency enables USACHPPM to accomplish many more noise consultations each year. Additional large operational cost savings can be realized in some situations at installations as a result of effective management of noise emissions from training and testing ranges and reliable decision guidance.

6.2 PERFORMANCE OBSERVATIONS

BNOISE2™ performed within expectations and is relatively easy to use, given the complexity of military training operations and acoustical propagation through the atmosphere. Because BNOISE2™ accounts for the very large (over 50 dB) statistical variance in received noise level due to weather changes, the statistically based predictions give a far superior picture of expected noise environment than can be obtained via short-term noise sampling. The GUI and ability to output contours in GIS format enhance the productivity of using BNOISE2™ in the current computer climate. The performance of BNOISE2™ would be enhanced by providing additional weather options, additional metric choices, and assessment protocol choices that enable more accurate assessment of community reaction to the noise produced by military testing and training. Efficiency would be further enhanced if the software operated in the GIS environment, so that installation data layers could be accessed for data input of information such as range and firing point locations.

6.3 OTHER SIGNIFICANT OBSERVATIONS

BNOISE2™ gives the DoD, public law enforcement agencies, and the private sector, a tool to predict the noise from military and explosive (e.g., mining) operations. BNOISE2™ can predict the value of a variety of single-event metrics, particularly SEL and peak metrics, in terms of statistical expectations for fairly broad classes of weather conditions. The time-averaged metrics such as Leq (equivalent sound level) and DNL are calculated using the single event SEL metric statistical variance.

BNOISE2™ single event predictions had been previously verified under known weather conditions; however, without detailed meteorological information (specifically, vertical variation of sound speed in the atmosphere), it is not possible to accurately predict where the noise level will fall within the expected statistical range at any particular time. Thus spot measurements cannot be expected to agree with model predictions. It is also somewhat problematical to use the noise model to verify compliance with a metric limit value, other than statistically. The model is

very useful for identifying changes in the noise environment due to changes in facilities of operations.

6.4 LESSONS LEARNED

This project provided the first opportunity to test BNOISE2™ accuracy and performance under conditions of actual training at an installation. The utility of the software for noise mitigation was demonstrated and showed extremely favorable cost performance. The importance of accurate training activity data was witnessed, particularly regarding the weapons and number of rounds fired on each range throughout the assessment period. Researchers concluded that there is a need to modify BNOISE2™ to offer the user a wider selection of weather conditions, which will be done as part of a planned software upgrade in the near future. The experience and data gained during this project, along with installation consultations, led the research team to conclusions regarding needed improvements in blast noise impact assessment methodology.

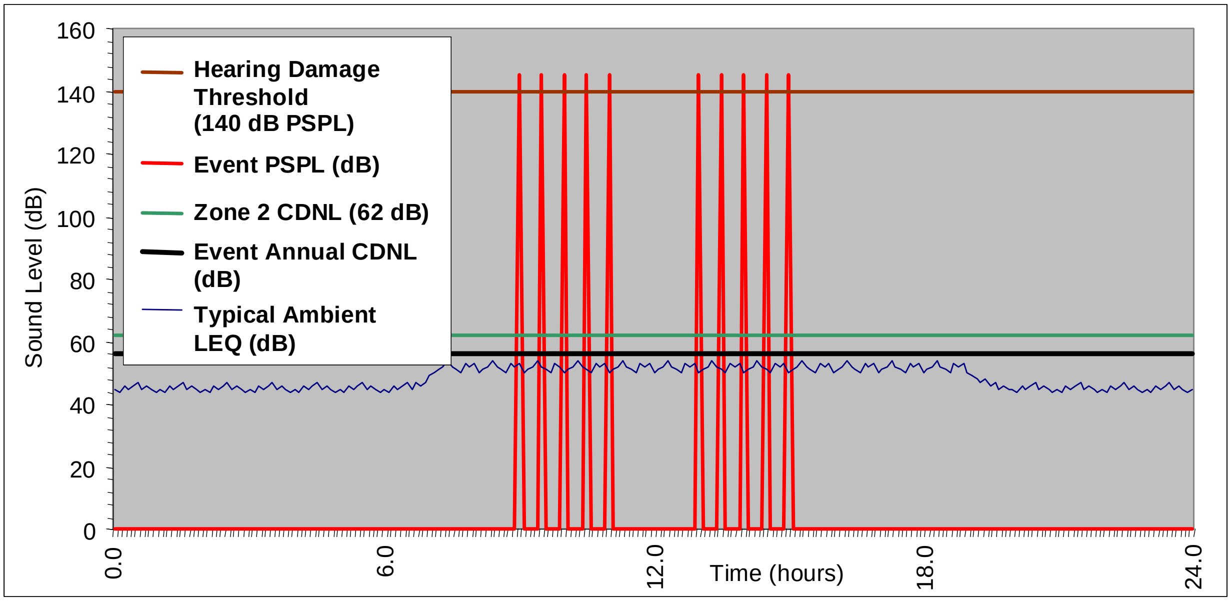
Schultz (1978) published a dose-response relationship for transportation noise based on data obtained by many researchers. This approach has been adopted internationally for virtually all types of noise, including high-energy impulsive noise (ANSI 12.9 Pt. 4, 2005; ISO 1996, 2003). Noise dose is measured in terms of a stimulus metric such as Leq or DNL that averages the total received sound exposure[2] (SE, defined as the time integral of pressure squared) over the assessment period, which is typically 1 year. The response metric is the percentage of the population that is "highly annoyed," measured by a social survey. Dose-response functional relationships describe the percentage of the population that is highly annoyed as a function of the average noise level. Acceptability criteria, in terms of acceptable noise metric values, have been established for various land use types, such as industrial, residential, and schools/hospitals, as shown in Table 1. Much of the data used by Schultz was obtained in the vicinity of busy highways and airports. It seems reasonable that average noise level assessment is workable for noise that is fairly consistent over time. Presumably, the annoyance response might also then be fairly constant with time.

This averaged noise methodology, applied to blast noise (CHABA, 1981) and later modified (CHABA, 1996), became Army policy as described in Chapter 7 of the Army Regulation 200-1 version dated 1997. An average high-energy (large weapons) noise level of 62-dB CDNL was deemed acceptable for all land uses including schools, hospitals, and residences. A dose-response model (CHABA, 1981) indicated that 13% of the population would be highly annoyed at this CDNL noise level.

Averaged noise can mask loud individual events that are potentially the most troublesome, as is illustrated in the notional example shown in Figure 10. In this illustrative example, 10 high-energy impulsive noise events of 145 dB peak sound pressure level (PSPL) occur during some time period. This peak level is very loud, well above the criterion of 130-dB peak for high risk of receiving noise complaints (Pater, 1976; USACHPPM, 1994). The calculated annual average level of these 10 events is 56-dB CDNL (assuming that the events occur during the daylight hours), which is well below the 62-dB CDNL deemed acceptable for even the most noise-

[2] Sound exposure is often referred to as "sound energy" but is in fact equal to acoustical energy only under certain conditions.

sensitive land uses and is 1 dB below the 57-dB LPUZ level. A total of 50 such events during a year would still yield an annual average level of less than 62-dB CDNL, so the average noise level would not reveal a serious problem. Clearly, averaged annual noise level can mask impulsive noise problems and give decision makers inadequate guidance. Developers could build residential housing in an area in which these conditions occur, which Army guidelines indicate is satisfactory, but which would almost certainly result in severe noise problems and eventual curtailment of the training operations that produce the noise.



PSPL = peak sound pressure level.

Figure 10. Hypothetical Illustrative Example Showing 10 Impulsive Noise Events and the Resulting Annual Average Level.

An alternate blast noise assessment protocol describes complaint risk as a function of the peak noise level of discrete impulsive noise events (Pater, 1976; USACHPPM, 1994), which was presented in Table 1. This assessment protocol has been adopted (AR 200-1, 2007) to supplement average noise level assessment for blast noise as a interim protocol pending research results that support a more effective assessment protocol. The complaint risk protocol is based on experience at installations, but lacks a rigorous research basis and does not account for the effect of number of events. It is also not clear that complaints are sufficiently indicative of community response to serve as the sole basis for noise management decisions, as is often the case in practice at installations.

Blast noise events are infrequent and highly variable, and anecdotal experience indicates that people respond negatively to the loudest events rather than to the average noise level. Noise complaints almost invariably occur in response to the loudest events. Long-term time-averaged noise level metrics mask loud events and are also problematic because of uncertainty regarding the number of events and because the average level is not heard by the receivers. The authors of this report hypothesize that adverse response to noise varies dynamically with noise level, as illustrated in the hypothetical example shown in Figure 11. Response may well be influenced by

the number and timing of noise events. Response will surely show considerable variance due to differences in individual tolerance to noise and other attitudinal and demographic factors. These hypotheses are in agreement with experience with surveys such as those that measure approval ratings of political officials or television programs. Further research is needed to determine an improved noise impact methodology for military weapons blast noise. Success will require a response metric to measure annoyance response dynamically as noise level changes. Suitable noise level acceptability criteria must also be developed. Noise impacts are currently managed at installations in response to noise complaints, especially congressional enquiries. A fairly small number of complaints is often sufficient to provoke changes in operational procedures that may diminish mission capability over the long term. Transportation noise criteria maintain that it is acceptable for all land uses for 13% of the population to be highly annoyed. Noise complaints are probably received from the most noise-sensitive segment of the population. Is the military giving away mission capability to please a small segment of the population? Improved blast noise impact assessment methodology is needed to provide installations with a basis for informed noise impact management decisions that will balance environmental quality and mission capability.

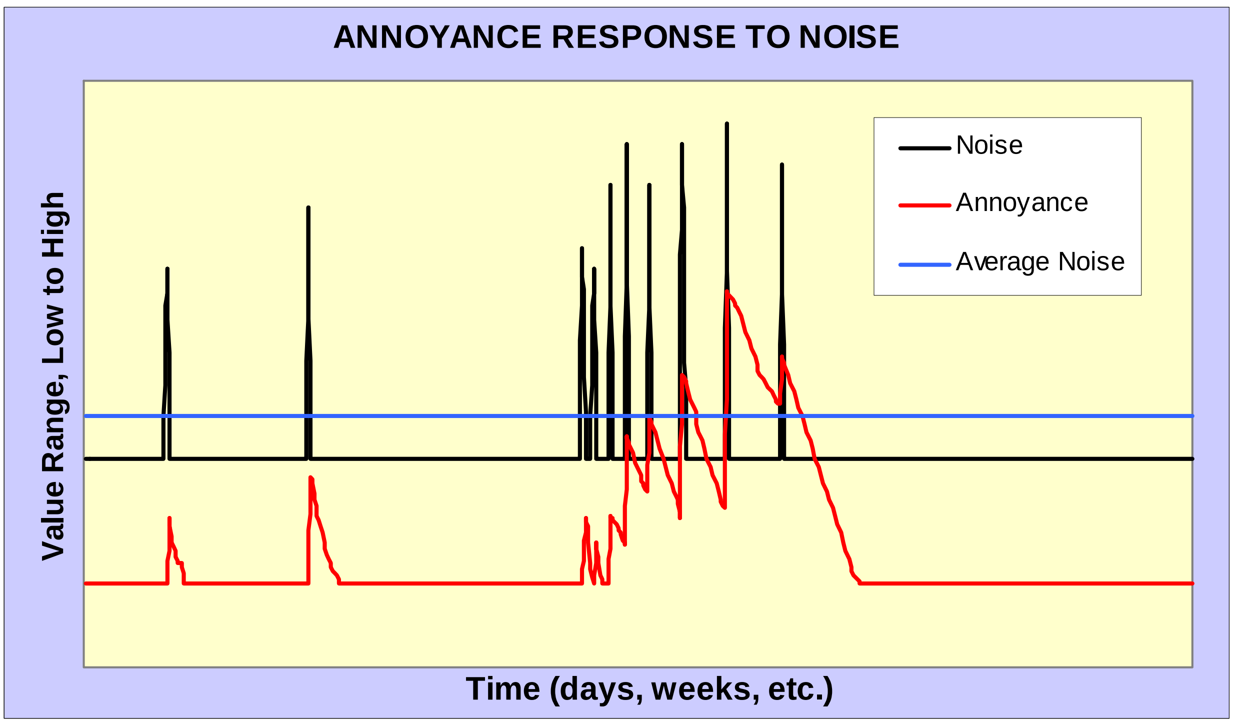


Figure 11. Hypothetical Example of the Dynamic Relation Between Noise Level and Adverse Response.

6.5 END-USER ISSUES

The primary end user is USACHPPM; others include installation personnel and contractors who perform noise assessments for installations, including master planners, trainers, and range operators. All of them are concerned about software accuracy, cost, and ease of use. BNOISE2™ can be used at virtually any location, including where terrain or unusual weather or the presence of large bodies of water may have significant effects on received noise level. The software runs

on common personal computers that utilize the Windows™ operating system. The U.S. Army developed the BNOISE2™ software and hence there are no proprietary considerations. Noise emission depends strongly on the type of weapons fired, which is dictated by training requirements. The noise dose in the community may be influenced by several other factors, particularly by the location of the firing, by the design and orientation of the range, by the time of day, by the weather conditions when the firing occurs, and by the number of noise events.

6.6 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

There are no national regulations regarding weapons blast noise. "Regulation" amounts to self-regulation to maintain noise at levels acceptable to community residents. This is done by a combination of technology, planning, and public outreach. BNOISE2™ is used by USACHPPM in consultation with installations to minimize noise problems, and is available to the installations and the public. USACHPPM and ERDC/CERL noise subject matter experts participate in the ANSI and International Standards Organization (ISO) as active members of working groups developing applicable standards and as voting members of the Acoustical Society of America S1, S3 and S12 Standards Committees. Participation ensures that standardized recommended practice provides appropriate treatment of U.S. Army-unique weapons blast noise. Also, this forum provides an opportunity to gain peer-reviewed credibility for weapons noise metrics and impact assessment protocols for blast noise.

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APPENDIX A

POINTS OF CONTACT

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Dr. William A. Russell, Jr.	USACHPPM MCHB-TS-EON 5158 Blackhawk Road APG, MD 21010	Phone: 410-436-3829 Fax: 410-436-1026 E-Mail: wlliam.russell4@us.army.mil	Project Manager, Principal Investigator

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APPENDIX B

GLOSSARY OF TERMS

A-Weighted Sound Level, A-Level – The ear does not respond equally to sounds of all frequencies but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound pressure level of a noise containing a wide range of frequencies in a manner approximating the response of the ear, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. Thus, the low and high frequencies are de-emphasized with A-weighting. The A-scale sound level is a quantity, in decibels, read from a standard sound-level meter with A-weighting circuitry. The A-scale weighting discriminates against the lower frequencies according to a relationship approximating the auditory sensitivity of the human ear. The A-scale sound level measures approximately the relative "noisiness" or "annoyance" of many common sounds.

C-Weighted Sound Level – The C-scale sound level is a quantity, in decibels, read from a standard sound level meter with C-weighting circuitry. The C-scale incorporates slight de-emphasis of the low and high portion of the audible frequency spectrum.

Community – Community means those individuals, organizations, or special interest groups affected by or interested in decisions affecting towns, cities, or unincorporated areas near or adjoining a military installation; officials of local, state, and federal governments; and Native American tribal councils responsible for decision making and administration of programs affecting those communities.

Day-Night Average Sound Level (DNL) – The 24-hr average frequency-weighted sound level, in decibels, from midnight to midnight, obtained after addition of 10 decibels to sound levels in the night from midnight to 7 a.m. and from 10 p.m. to midnight (0000 to 0700 and 2200 to 2400 hr). Frequency weighting may be used that is appropriate for the sound spectrum.

Decibel (dB) – The decibel is a logarithmic unit of measure used for quantities whose values are of interest over a wide range. Decibels are used for many quantities in electrical engineering and acoustics, including voltage, energy, power, peak sound pressure, average sound pressure, and sound exposure.

Demonstration – For the purposes of this report, demonstration refers to the use of computer software to calculate and display noise contour. Demonstration did not include field monitoring.

Equivalent Sound Level (Leq) – The level of a constant sound which, in a given situation and time period, has the same energy as does a time varying sound. For noise sources, which are not in continuous operation, the equivalent sound level may be obtained by summing individual sound exposure level (SEL) values and normalizing over the appropriate time period.

Frequency – Number of complete oscillation cycles per unit of time. The unit of frequency is the Hertz .

Hertz – Unit of frequency equal to one cycle per second.

Impulse Noise (Impulsive Noise) – Noise of short duration (typically less than one second), especially of high intensity, abrupt onset, and rapid decay, and often rapidly changing spectral composition. Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of firearms, the passage of supersonic aircraft (sonic boom), and many industrial processes.

Land Use Planning Zone (LUPZ) – DNL noise contours (57-dB CDNL) represent an annual average that separates the Noise Zone II from the Noise Zone I. Taking all operations that occur over the year and dividing by the number of training days generates the contours. But the noise environment varies daily and seasonally because operations are not consistent through all 365 days of the year. In addition, the Federal Interagency Committee on Urban Noise document states "Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider." For residential land uses, depending on attitudes and other factors, a 57-dB CDNL may be considered by the public as an impact on the community environment. In order to provide a planning tool that could be used to account for days of higher than average operations and possible annoyance, the LUPZ contour is being included on the noise contour maps.

Noise – Any sound without value. Unwanted or undesirable sound.

Noise Exposure – The cumulative acoustic stimulation reaching the ear of a person over a specified period of time (e.g., a work shift, a day, or a lifetime).

Noise Zone III – Noise Zone III consists of the area around the noise source in which the level is greater than 70-dB CDNL for large caliber weapons. Noise-sensitive land uses (such as housing, schools, and medical facilities) are not recommended within Noise Zone III.

Noise Zone II – Noise Zone II consists of an area where the DNL is between 62- and 70-dB CDNL for large caliber weapons. Land within Noise Zone II should normally be limited to activities such as industrial, manufacturing, transportation, and resource production.

Noise Zone I – Noise Zone I includes all areas around a noise source in which the day-night sound level is less than 62-dB CDNL for large caliber weapons. This area is usually acceptable for all types of land use activities.

PK15(met) – The peak sound level, taking into account the statistical variations caused by weather, that is likely to be exceeded only 15% of the time (i.e., 85% certainty that sound will be below this value). This metric gives the installation and the community a means to consider the areas impacted by training noise without putting stipulations on land that would only receive high sound levels under infrequent weather conditions that greatly favor sound propagation. PK15(met) does not take the duration or the number of events into consideration, so the size of the contours will remain the same regardless of the number of events.

Sound Exposure Level (SEL) – The level of the sound pressure squared, integrated over a given time.

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APPENDIX C

NOISE COSTS TO THE ARMY

This analysis provides an estimate of the impact of training and testing noise on Army operating budgets. Not all these costs can be addressed through use of noise assessment software, and the benefit directly attributable to BNOISE2™ would be highly dependent on the situation. This cost analysis addresses noise types that are Army-unique and will not receive adequate attention if DoD does not address them. These noise types are helicopter, blast (artillery, armor, detonations), and small arms noise. The cost of dealing with the effects of noise on threatened and endangered species is included here since the assessment of such effects relies heavily on the tools and technology developed by the Army noise R&D program. Effects of noise on domestic animals are also included here in damage claims. Costs are calculated based on damage claims, complaint handling, range and firing point closures, NEPA and Installation Operational Noise Management Program (IONMP) assessment costs, acquisition of new land, and impact on training and testing capability. Training and testing capability impacts include loss of training hours, loss of use of training acres, rescheduling training and testing, modifying training procedures, and the consequences of inadequate training. All costs are estimated in terms of FY05 dollar value, not adjusted for inflation.

<u>DAMAGE CLAIMS:</u> Each year, damage claims directly attributable to noise, with a total value of about $16 million, are submitted to the Army Claims Service (ACS). About $250,000 in claims are paid each year by the ACS. This doesn't include claims smaller than $25,000, which are handled locally. It is estimated that total damage claims paid Army-wide amount to about $900,000 per year. This $900K does not include the processing cost, which can be estimated to average about 40 man hours (MH) x $65/hr which equals $2,600 each. If the total number of claims is estimated to be 800 claims per year, the estimated processing cost is $2.08 million. Thus the total cost of damage claims is about *$3.23 million* per year. With improved technology, better technology transfer, and better coordination via a user group, it is estimated that this cost could be reduced by 20%. Without a noise program, there would be a lack of information regarding validity of noise damage claims, many invalid claims would be paid, and valid ones would be denied and would lead to expensive litigation. The cost could rapidly escalate.

<u>COMPLAINT HANDLING:</u> Haphazard handling of complaints results in damaged community relations, which results in escalated complaints and many more resources and man hours spent dealing with the consequences. The time per complaint in the aggregate can easily amount to 30 MH x $65 which equals $1,950. A typical installation may receive 30 complaints per year. This occurs at perhaps 100 installations, including Army Reserve and National Guard. Thus the total annual cost can be evaluated as $1,890 x 30 x 100 which equals *$5.85 million*. Improved methods, using a tested complaint management system based on experience and disseminated via improved tech transfer, can reduce costs by an estimated 20%. Each complaint can be handled more efficiently and also more appropriately, avoiding escalation. Without the program and without effective technology transfer, the losses would grow with time as more planning and design errors accumulate and result in more complaints.

RANGE CLOSURE: Ranges have been closed and use of firing points discontinued because of noise. Estimating that a range is closed on average once every 2 years and must be replaced at an average cost of $10.6 million, the annual cost per year is $5.3 million. Artillery-type firing points cost about $325,000 to plan and construct. Army-wide, it is estimated that 10 firing points per year are impacted by noise complaints. This impact generally requires relocation to sites more internal to the installation and away from boundaries. At a planning and construction cost of $325,000 per firing point, a total of $3.25 million is spent, a portion of which could be avoided with proper noise management capability. Therefore, the total cost of losing the use of ranges and firing points is thus estimated to be *$8.55 million* per year. (Note that, unlike firing points, lost ranges are not readily replaced due to Military Construction, Army (MCA) timeframes, and replacement is not considered in this assessment, only the value of the lost range. This loss could be reduced by an estimated 20% by proper siting and design of new ranges and by improved management of existing ranges and firing points. Without the program, without effective technology transfer, and without a user group to help disseminate information and technology and lessons learned, losses would grow with time as more planning, design, and operations management errors accumulate, resulting in the closure of more ranges and firing points.

LAND ACQUISITION AND ENCROACHMENT: Land is often acquired to mitigate severe noise problems. Recent and planned acquisitions of land reported by G-3 as a result of their land acquisition and Army Compatible Use Buffer (ACUB) programs indicate that land acquisition costs in U.S. Army, Pacific ranged from $61 to $13,552 per acre. Recent acquisitions by Forces Command (FORSCOM) National Training Center, California, and Training and Doctrine Command (TRADOC), Fort Lee, Virginia, were $2,233 and $4,505 per acre, respectively. Most land acquisitions are motivated by several factors; the most common are noise and Threatened and Endangered Species (TES) and it is estimated that 50% of land acquisition cost can be attributed to noise. Impacts associated with noise are a result of human population. While land acquisition costs away from populations may be in the thousands of dollars, acquisition costs of buffer near populations can be in the tens of thousands. For noise economic analysis, it is assumed that land acquisition has an average value (improved and unimproved) of $6,500 per acre. In addition to the more programmatic G-3 program identified above, the U.S. Army, Marine Corps, and National Guard acquire more than 2,500 acres per year in local purchases for mitigation. Recent examples include Camp Dodge, Iowa; Fort Polk, Louisiana; Fort Campbell (130 acres near the Sabre Army Heliport), Kentucky; and Fort Bragg/Pope Air Force Base, North Carolina (100 acres and 10,000 acres near Simmons Army Airfield). Other installations are considering substantial land acquisitions to avoid encroachment and accompanying noise problems; at least one of these may amount to as much as $150 million. Using the conservative figure of 2,500 acres acquired per year, it is calculated that costs for total land acquisition is 2,500 x $6,500, which equals $16.25 million per year (in fact, the ACUB program Army-wide is funded at $20 million per year). With improved methods of noise management, the cost of land acquisition could be decreased. Assuming that improved noise management and mitigation technology could reduce the 50% of land acquisition due to noise by 20%, the overall reduction of cost is 10%, or *$8.125 million* per year. Without the noise program, the situation could become much worse. Much more land would be acquired in an attempt to mitigate noise problems.

NEPA AND IONMP ASSESSMENT: IONMP is mandated by AR 200-1. NEPA Environmental Assessment (EA) and Environmental Impact Statement (EIS) procedures usually show noise to be a leading issue. ERDC/CERL and USACHPPM get many phone calls each year asking for help on these issues. Noise dose assessment models such as BNOISE™ and Small Arms Range Noise Assessment Model (SARNAM™) are essential to assess impacts. In recent years, IONMP and NEPA studies were done about every 5 and 4 years, respectively. For the next several years, the number of IONMP and NEPA studies will be much higher because of BRAC, transformation, modularity, and re-stationing. It is estimated that each will be required about every 2 years at a typical installation. A typical IONMP study costs about $160,000. Significant IONMP studies are done at about 75 installations, for an annual cost of $160,000 x 75/2 (every 2 years) which equals *$6 million*. A typical NEPA study costs $2.2 million, about 10% of which can typically be attributed to noise. Such documentation is typically needed at perhaps 100 installations. A cost estimate is thus $2,200/2 (every 2 years) x .1 (attributed to noise) x 100, which equals *$11 million*. Total annual cost of preparing the required reports is thus estimated to be *$17 million*.

This does not include the cost of staff time required to shepherd an IONMP, EA, or EIS through the multiyear process from conception to completion. Assume a man year of labor costs of about $128,000, including burdens ($65 per hr x 1,970 hr). An average IONMP requires perhaps 1/2 man year of installation staff time, a cost of $64,000. An average EA or EIS typically requires much more effort, perhaps a total of 2 man years, or a cost of $256,000. The staff cost attributable to noise is thus estimated to be IONMP $64,000 x 75 installations/2 (every 2 years) + NEPA $256,000/2 (every 2 years) x .1 (attributed to noise) x 100, which equals *$3.68 million*. Total annual cost is thus *$20.68 million*. With improved technology and transfer of same, including to private contractors who often execute these studies and to installations so they can be smart buyers, costs can be reduced by at least 20%. Without the program, current tools will quickly become obsolete as new weapons are introduced and as adversaries demand the use of modern sophisticated technology. Calculation of noise contours for installations' noisy operations demands automated calculation tools because of complexity and computational labor. Without such tools, NEPA and IONMP would be unsatisfactory. The consequences are substantial and would grow with time.

REDUCED TRAINING CAPABILITY: Noise insidiously compromises training by preventing some types of training from being carried out because of noise impacts or because of loss of training facilities. An inadequately trained soldier is at risk, and his combat mission is also put at risk. Estimating the dollar cost of the death of a soldier is a problematic issue. Estimating the cost of not achieving a combat objective could be extremely large but is also difficult to estimate accurately. To maintain credibility, the estimate of reduced training capability is based strictly on the cost of loss of training hours, rescheduling training, and modifying training procedures. Included is all training throughout DoD that will benefit from the noise management tools developed by this program. An hour of training for each trainee, including range operation and maintenance, support personnel, and equipment, is estimated to cost $130. Total training of an estimated 650,000 troops (Army, Army Reserve, and Army National Guard) can involve on average 100 hr of noise training per trainee per year. Such training occurs on at least 33 installations (10 FORSCOM, 10 TRADOC, eight Army National Guard, and five Army Materiel Command [AMC]). The total cost of such noise training can be estimated according to 650,000

x 100 hr x $130, which equals $8.45 billion. Conservatively, if only 5% of this noise training is compromised by noise impacts (5 hr per trainee), the cost is *$422.5 million*. These costs are due to such work-arounds as adjusting schedules, adjusting munitions charge, periodic shutdowns for compliance, etc. Additional hidden costs, particularly transportation costs, accrue due to relocation of training because of noise. These costs easily amount to an average of $200 per troop each year, for a total of 650,000 x $200, which equals *$1.3 million*.

Testing is often canceled or rescheduled because of possible nose impacts. This is expensive because many dedicated labor costs continue whether or not testing is carried out. It is estimated that these costs are about $3,300 per hr at a typical testing range such as Aberdeen Proving Ground or Yuma Proving Ground and that a total of at least 1,000 hr of such costs are experienced each year Army-wide, for an additional cost of *$3.3 million*. The total cost of reduced training and testing capability due to noise is thus estimated to be *$555.8 million* per year. With improved noise management, the loss of training hours, and thus the associated monetary loss, can be substantially reduced by an estimated 20%. Without noise management technology, the impacts of noise on training capability would grow rapidly.

<u>COST AVOIDANCE SUMMARY:</u> The <u>annual</u> costs of noise problems that resulted from the response of humans to loud training noise, as estimated above, totaled more than *$602 million* in FY05 dollars, without accounting for the possible cost of loss of life or unachieved combat objectives. In general a 20% reduction in cost, which is realizable by developing and applying noise tools and technology in combination with a proactive public relations effort, is a cost avoidance of *$1.276 million (net present value [NPV])* through FY22 (10 years after final demonstration/ validation). This cost reduction is based on an assumption that the Environmental Technology Management Plan (ETMP) is fully funded and all the exit criteria are thus met. It also assumes interim improvements in cost reduction as various technologies are completed, starting with 2% reduction in FY08 and FY09, 8% in FY10, 10% in FY11, 13% in FY12, and finally, a full 20% reduction in FY13 through FY22 (and beyond). This incremental improvement is due to incremental improvements in existing capabilities and spiral development/deployment of other capabilities.

The Army will realize additional cost avoidance because the noise technology developed under this Environmental Technology Management Plan (ETMP) will find application in other fields, for example, threatened and endangered impacts and encroachment. These are not included in the current analysis.

<u>INTANGIBLE BENEFITS:</u> An important aspect of encroachment-related noise problems is that it may not be feasible to replace training lands, simply because suitable lands are not available at any price to create a new training facility equivalent to installations such as Fort Carson, Fort Hood, Fort Lewis, Fort Stewart, Fort Benning, etc. Thus a great value of intelligent noise management is sustaining training capability on existing training lands.

Noise management also produces qualitative benefits. Lower noise levels will result in improved quality of life for both Army personnel and the residents of the region surrounding Army and National Guard installations. Fewer noise problems will help to ensure that Army personnel are well trained, will remain in the Army, and will be able to carry out combat missions with greater

effectiveness and reduced losses. An effective and proactive noise management program greatly improves relations with the surrounding community.

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